Hall probe bench prototype

for closed magnetic structures

ALBA Synchrotron Light Source,
Engineering division, Transversal section

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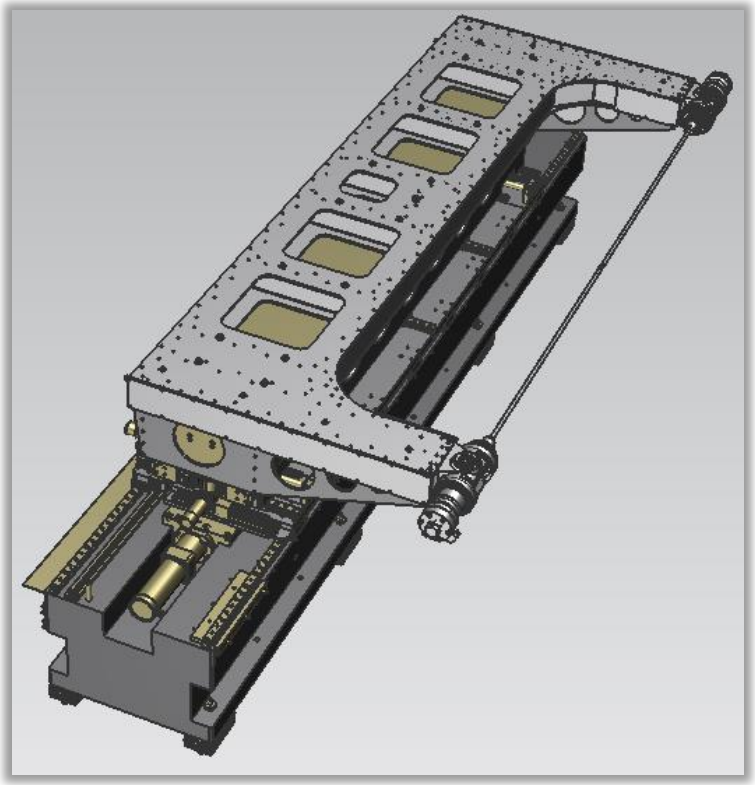
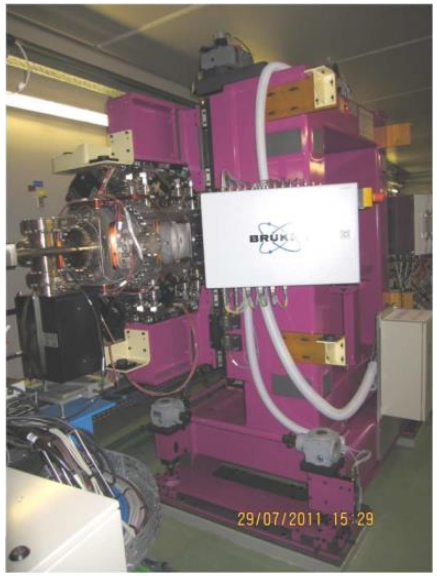


Summary

- *Requeriments*
- *Concept*
- *Validation*
- *Prototype Specifications*
- *Conceptual design: and dimensions*
- *Materialization and Description*
- *FEA*
- *Mounting*
- *Results*

Requirements



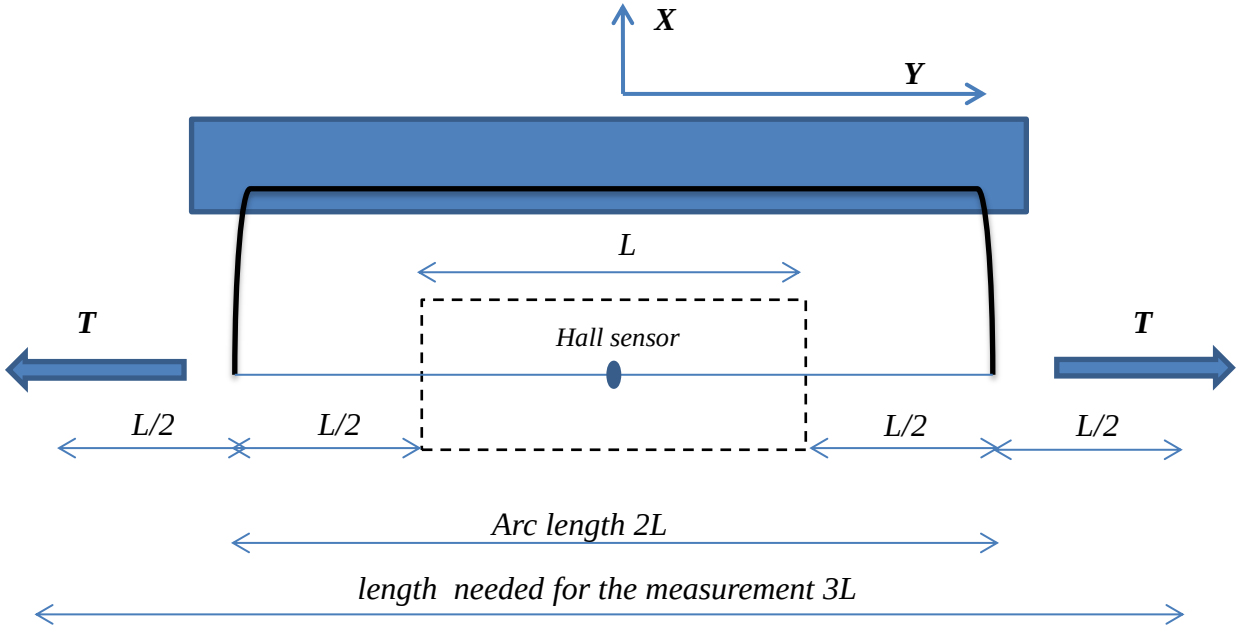
Requeriments

- Upgrade to the ID lab to measure closed magetic structures
- Long longitudinal Measuring ranges (up to 3 m)
- Vertical and transversal direction scans
- Small Guidance error on positioning the hall sensor (order of 0,05 mm)
- Very small angular deviations (order of 0,05 mrad)

concept

Simple Idea

- Hall sensor attached on a string tensioned on a C shaped arc structure
- The string is passing through the closed magnetic strucure
- The arc is moved by an accurate positioner



THIS CAN WORK??...

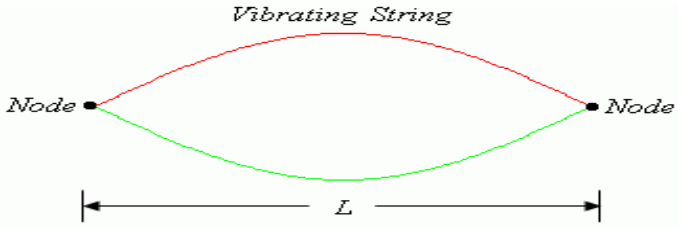
- **We are able to materialize that arc and move it with a positioner of a precision level of a machining tool**
- **We will need a lot of space and we have it**
- **Is a string stable enough once is tensioned?**

Validation

The Vibrating string

A string under tension has a mode of vibration on the first harmonic which frequency depends on the **vibrating lenght**, the **tension** and the **linear mass**.

$$f = \frac{1}{2 * L} * \sqrt{\frac{T}{\mu}}$$



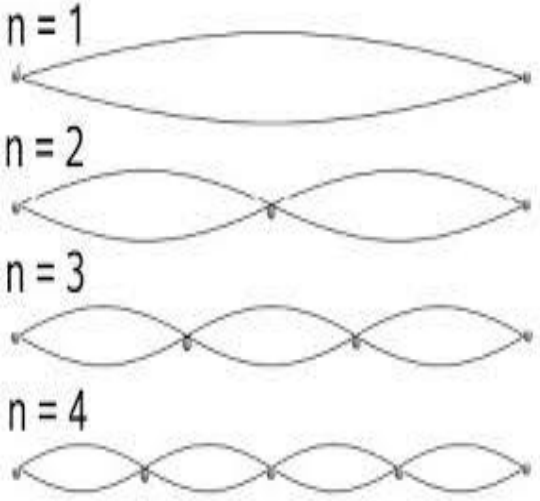
When this is excited, will have direct impact on the positioning accuracy of the hall sensor.

Calculation of the 1st harmonic vibration

- L ∼ 4000 mm
- Area 24x1,4 mm2
- Material Pultruded carbon fiber d=1600Kg/m3
- Elastic limit 2800 Mpa

T = 7,5kN → *f* = 55 Hz → stress = 223 Mpa

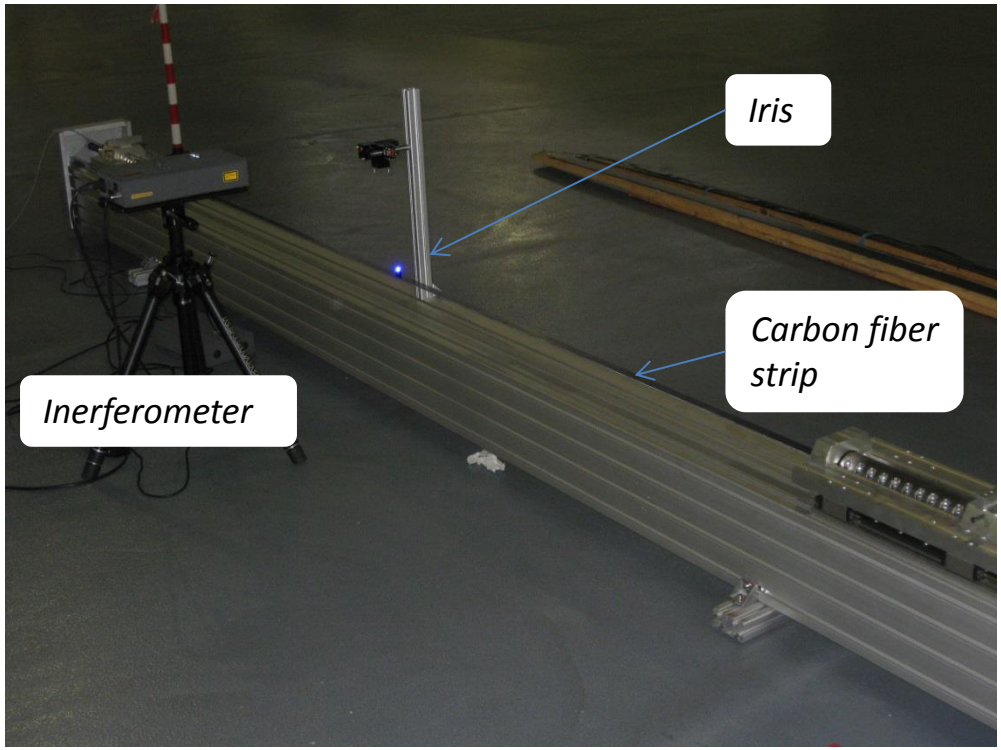
At ALBA enviromental low frequencies are considered under 30 Hz
This value is taken as a reference when designing in a safe margin

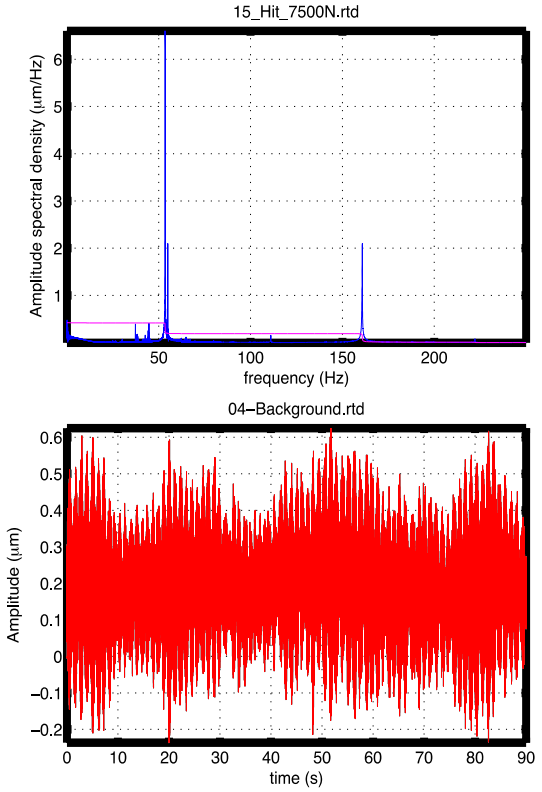


Validation

Empirical exercice

- Evaluate fundamental frequency modes of a tensioned strip of the same section calculated previously
- Inducing external excitation for amplification checking
- Very simple exercise to confirm the analytical values of the frequencies and the amplitude





Specification and parts

Ranges.

X : ±125 mm
Z : ±50 mm
Y : 1200 mm
Chamber allowance (“stay clear” area) = 600 mm

Longitudinal POSITIONING ERROR

dX, dY, dZ < 0,05 mm

Angular POSITIONING ERROR

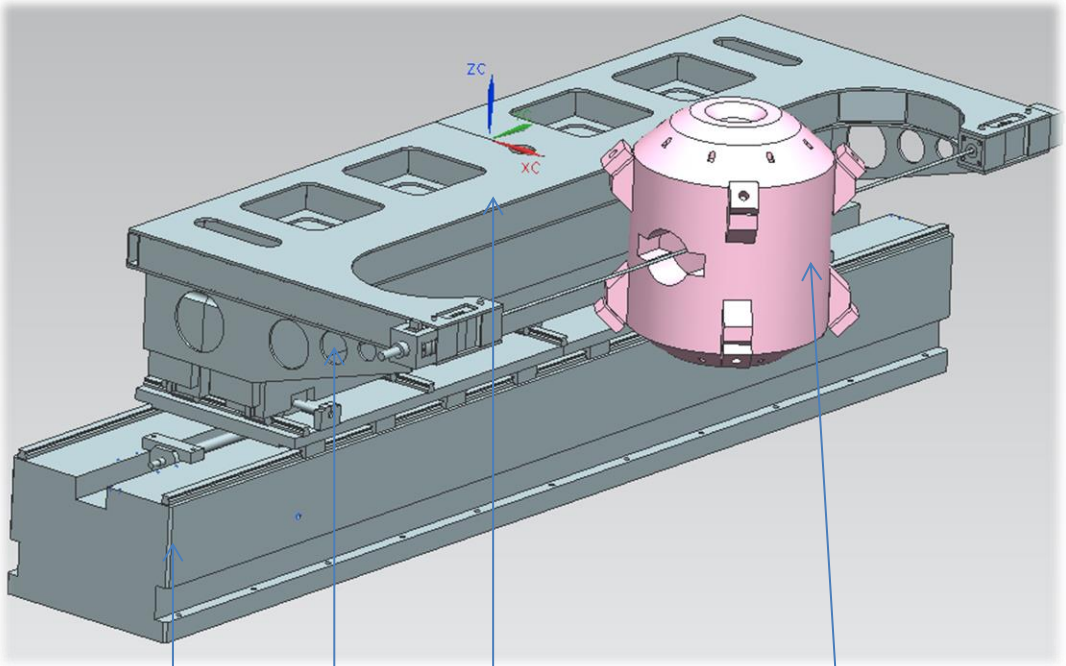
Roll dα, Pitch dβ < 0,05 mrad
Yaw dϕ < 0,1 mrad

Repeatability

X, Y, Z ≤ 0,03 mm

Speed

Y ∿15 mm/s



XY stage

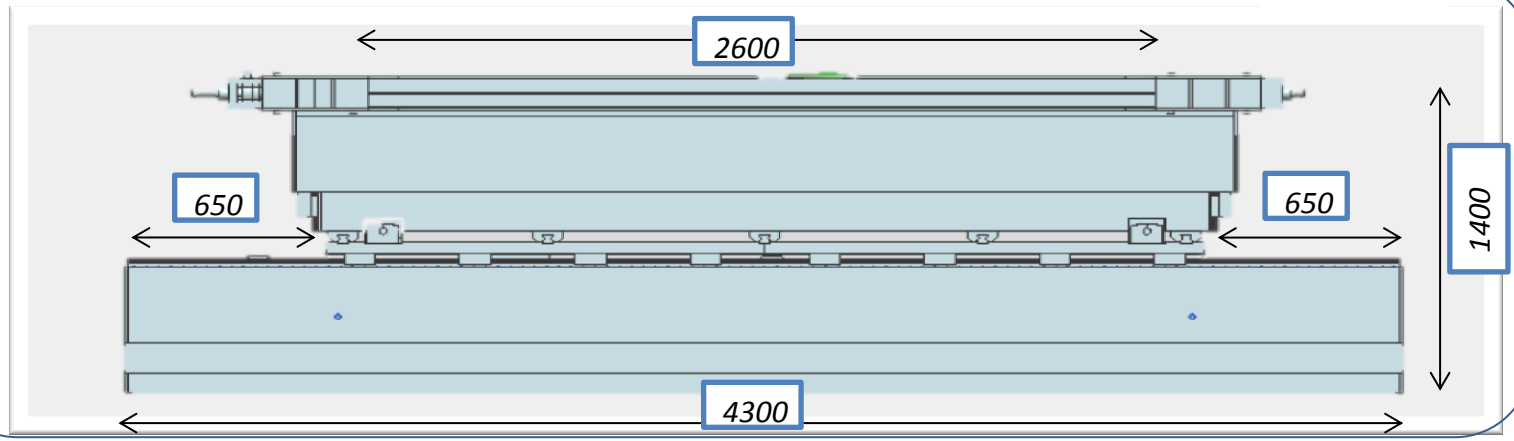
Z stage

Arc structure with carbon fiber strip

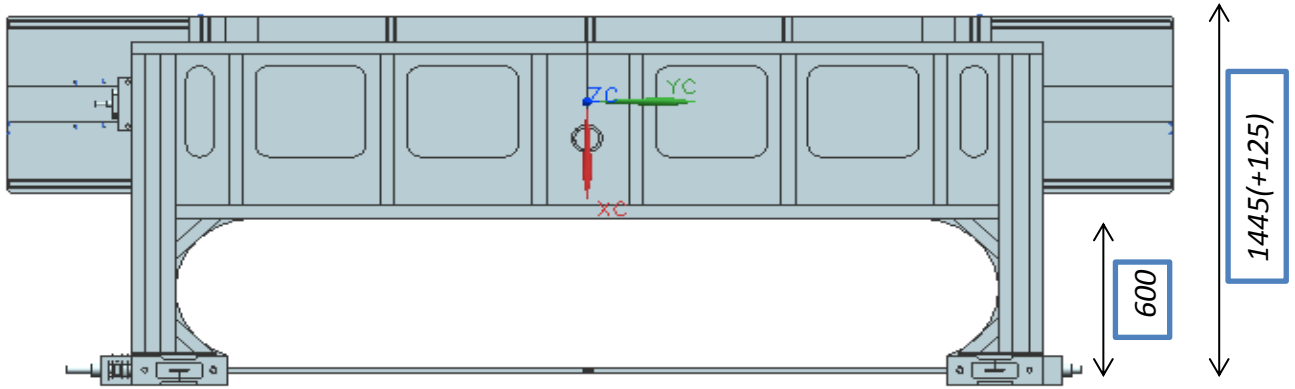
Closed Magnetuc structure

Dimensions

Side View



Top View



Materialization: arc structure

Strip dimensioning

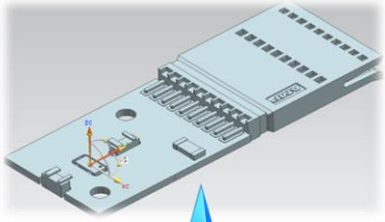
- Area 16x1,4 mm2
- Vibrating length **2600 mm**
- d = 1600 Kg/m3
- Tensioning force **0.5 TN**

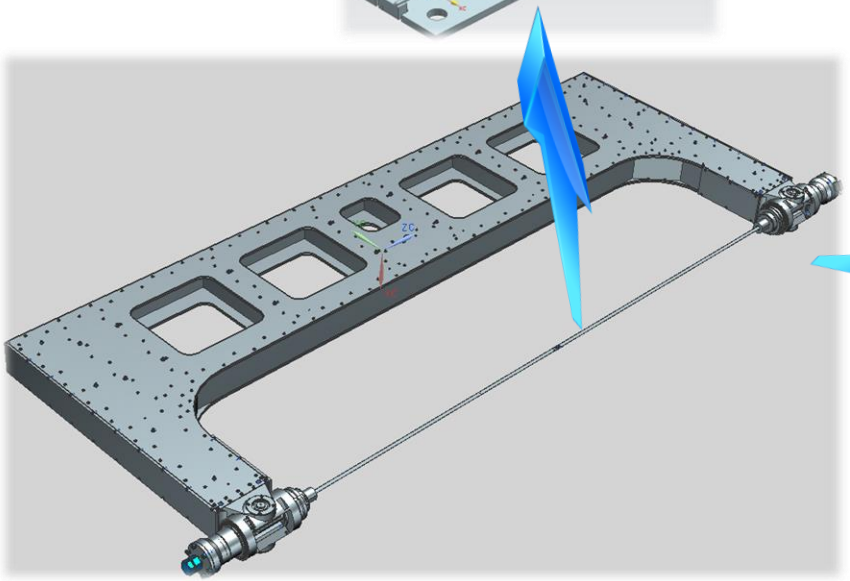
Results

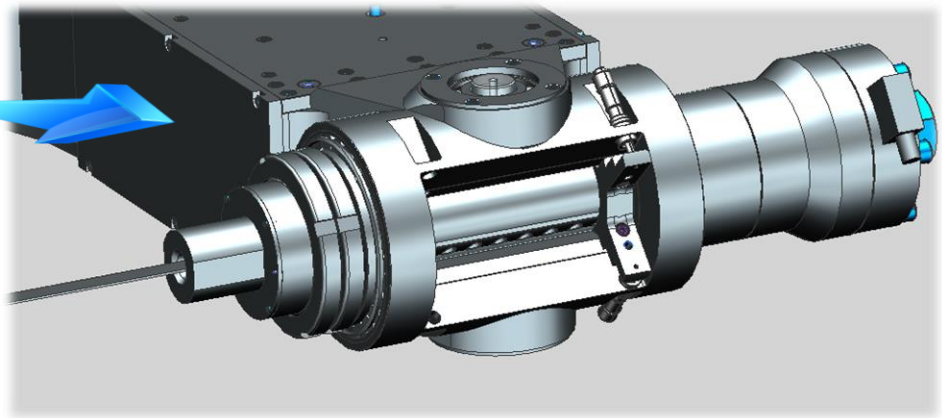
- Stress = 223 Mpa
- Security factor = 13
- ***f*1 = 71 Hz**
- Elongation ∼ 4 mm

Arc structure

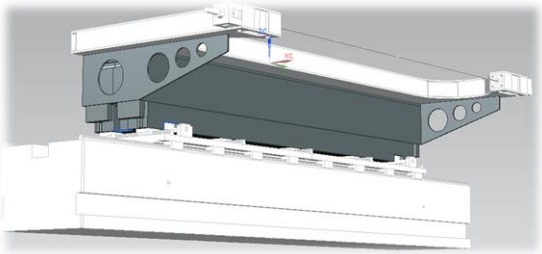
- Aluminium profile structure
- Two tensioning blocks one with stretching gauge
- Mass arround 400 Kg

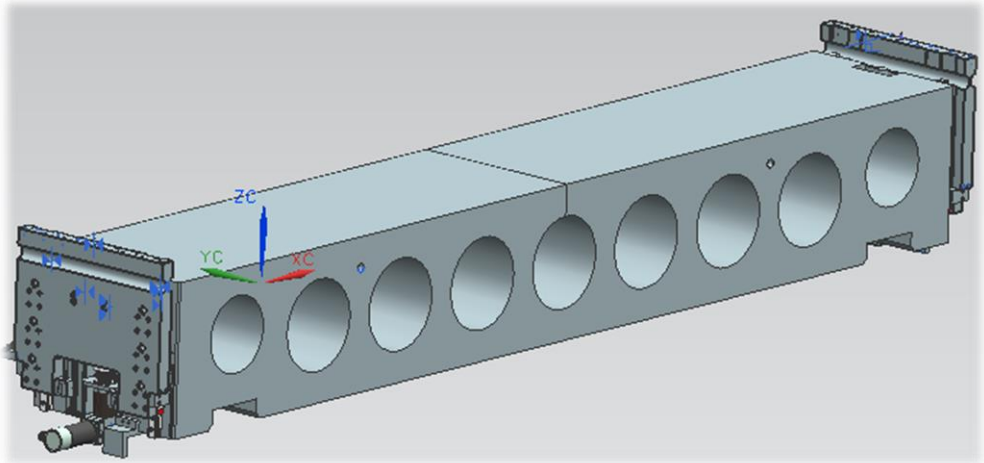






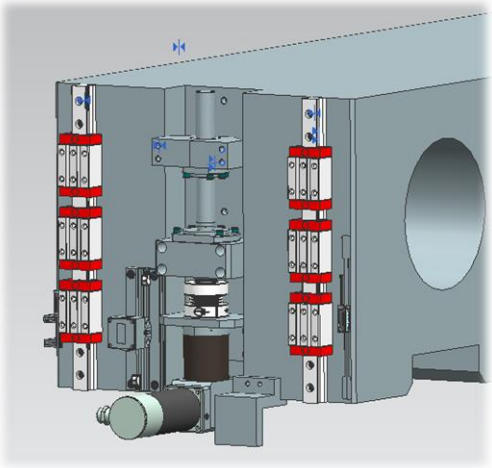
Z stage



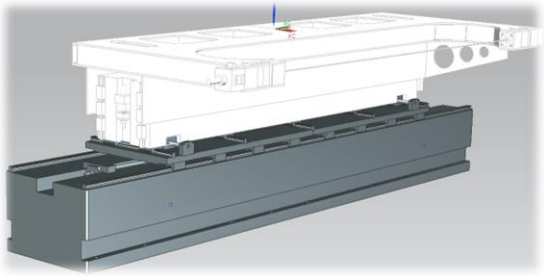


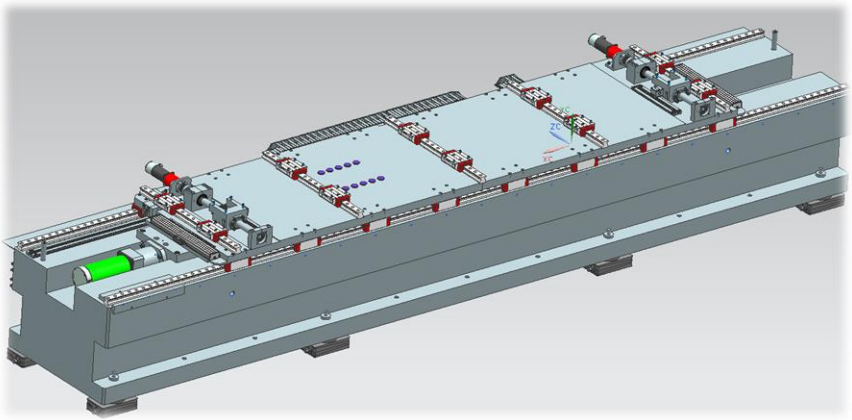
Z stage

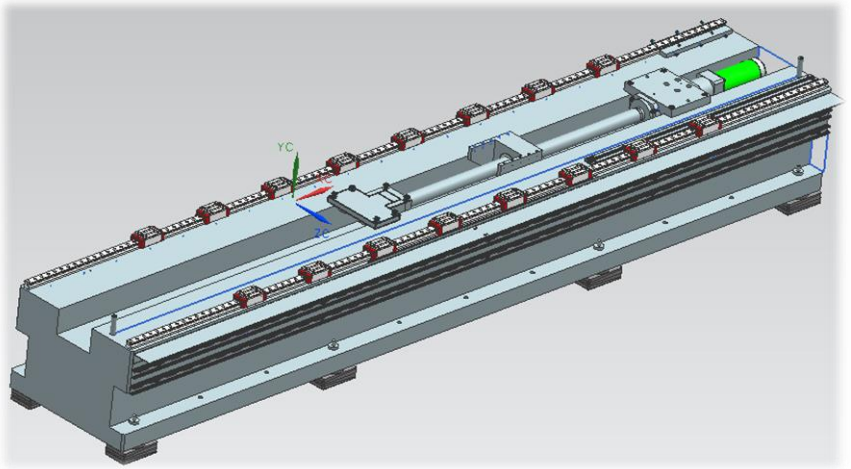
- Double flexure system on a granite block
- Compact design: with a single step Z&pitch
- Allows Z range of 100 mm and tilt about 0,2º
- Flexures on high modulus material
- Preloaded guiding system and grinded spindles
- Movement for each flexure is encoded
- Mass of that assembly arround 1.2 Tn



XY stage



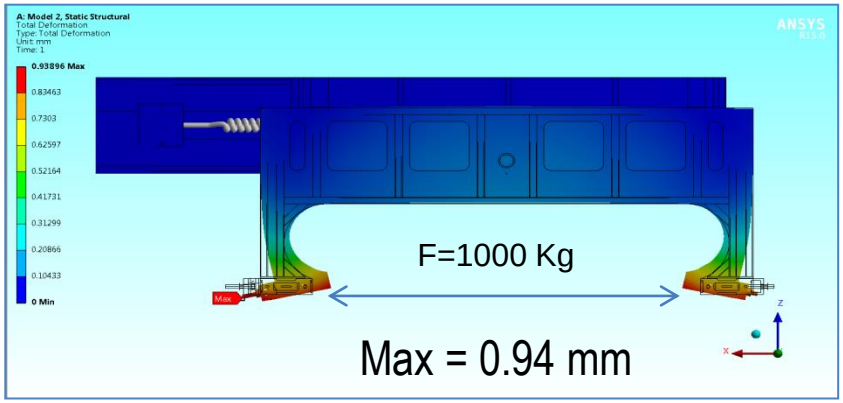


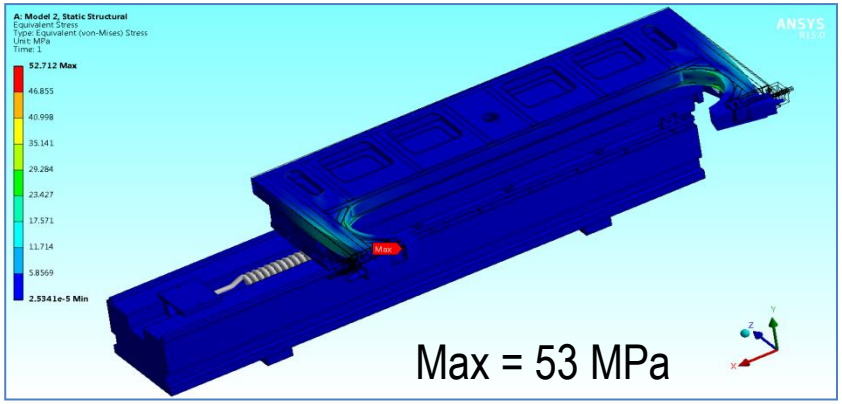


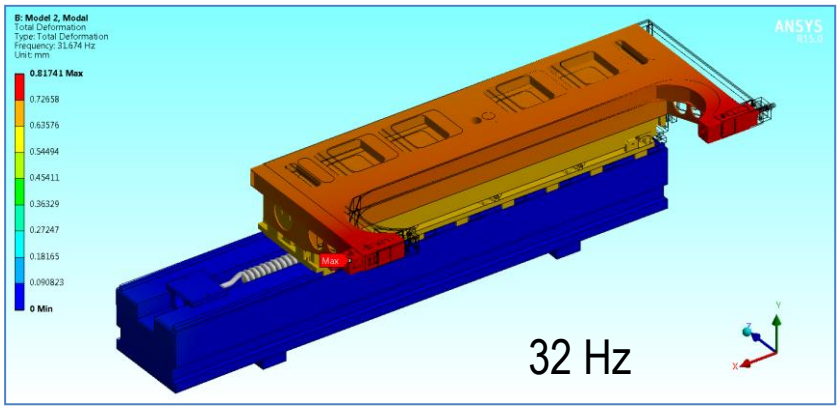
XY stage

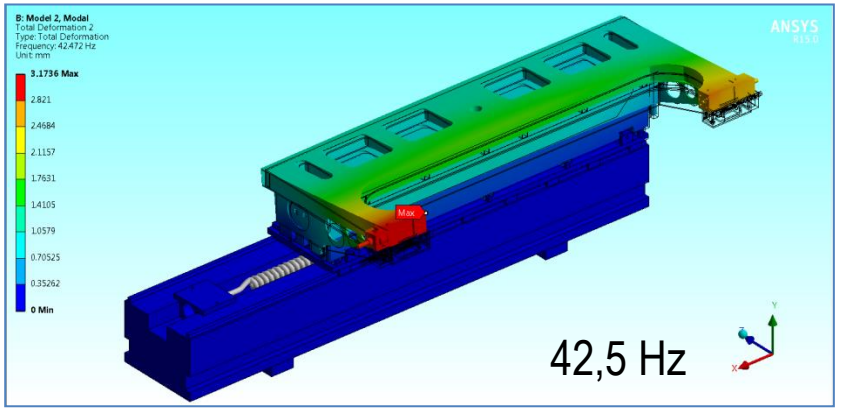
- X stage 2 actuators are implemented to avoid rotation on the vertical axis due to the long beam
- Y stage: **Measurement axis**: All mounted on a granite block
- Preloaded roller and matched guides
- Separation between those guides affect on the vertical accuracy
- Mass of the XY stage 5 Tn

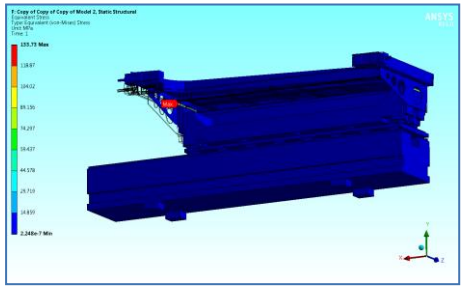
FEA calculation

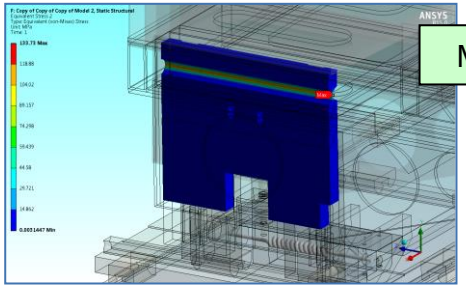












Max = 134 MPa

Mounting

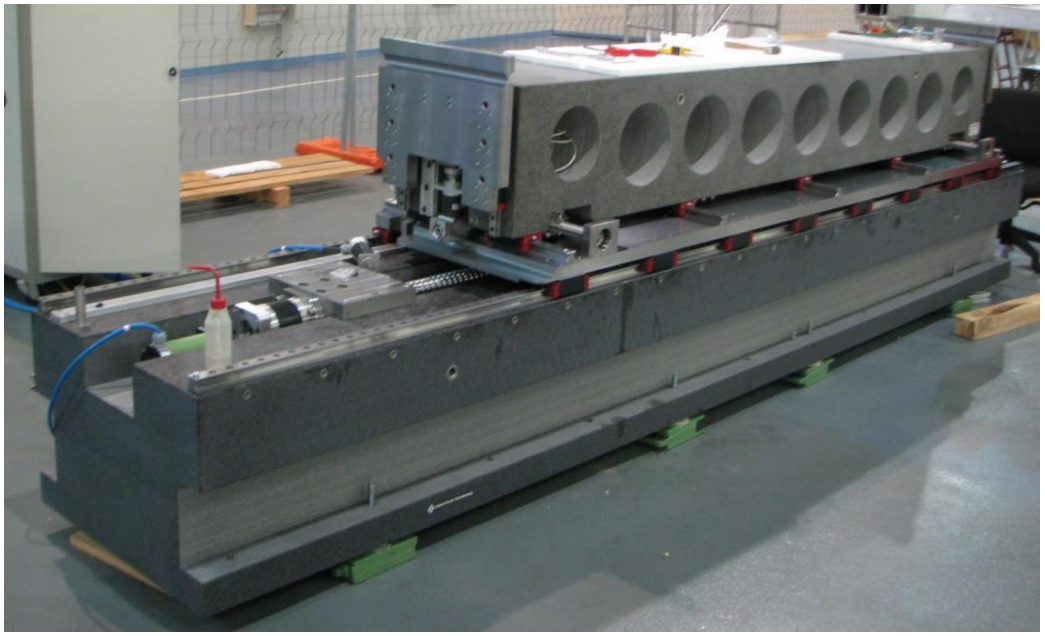
XY stage

- Verification of the components with alignment and metrology group
- Big granite block is aligned flat on respect to the floor.

XY stage

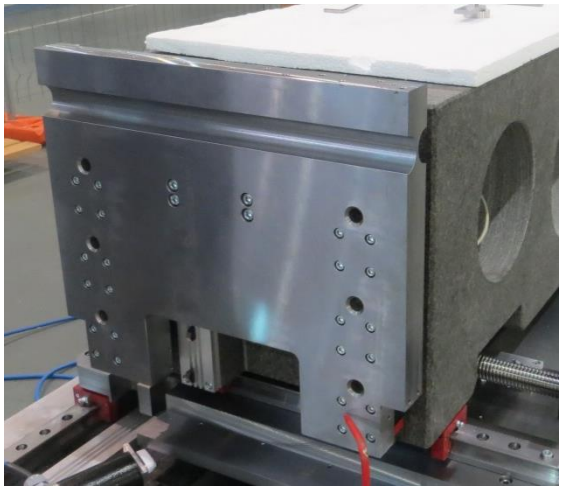
- Interface plate fitted in top. Checking the slots where the transversal guides are. Grinding was corrected.several times
- Very **accurate** alignment of the sets of linear guides

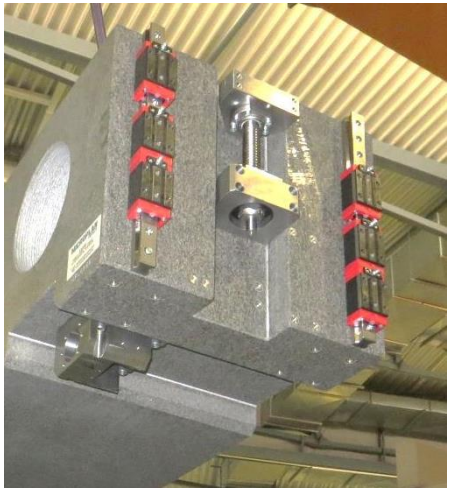
Mounting II



Z stage

- Hollowed granite block is located on top of the XY stage
- The assembly is stopped to test the motors and perform some measurements to test the actuator



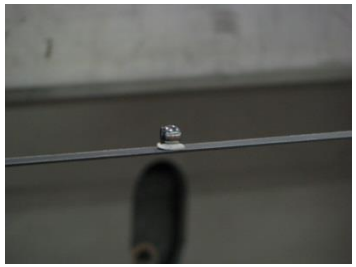


Mounting III

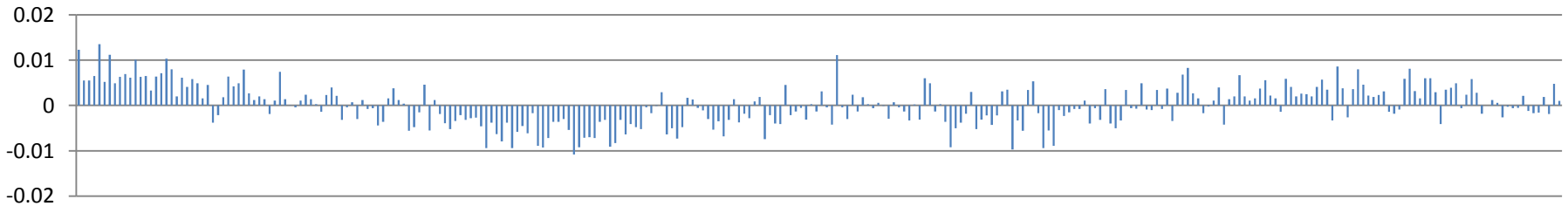
Arc structure

- Stretching system
- Carbon fiber is cutted by water
- The assembly is stopped to test the motors and perform some measurements to test the actuator
- C structure and stretching system are mounted in parallel
- Carbon fiber is tensioned up to **1Tn**

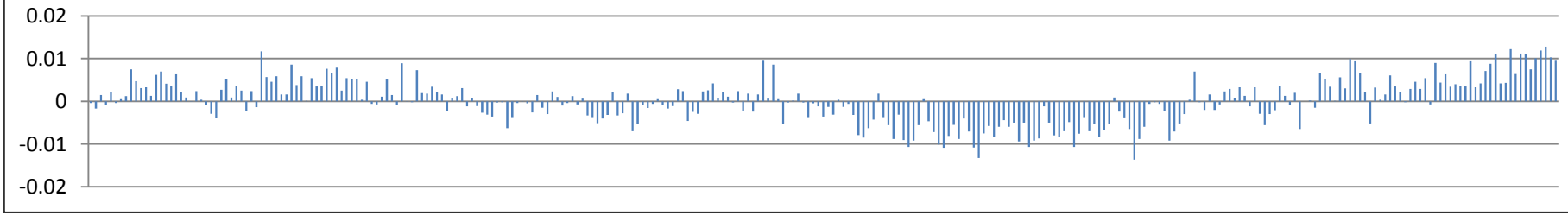
Results: Y Scan



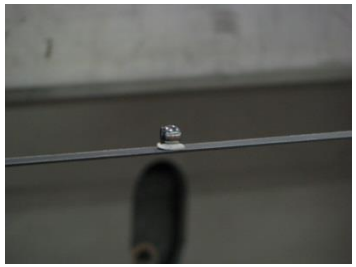
LONGITUDINAL MOVEMENT – Measure of the straightness at 1200 mm scan (+ direction)



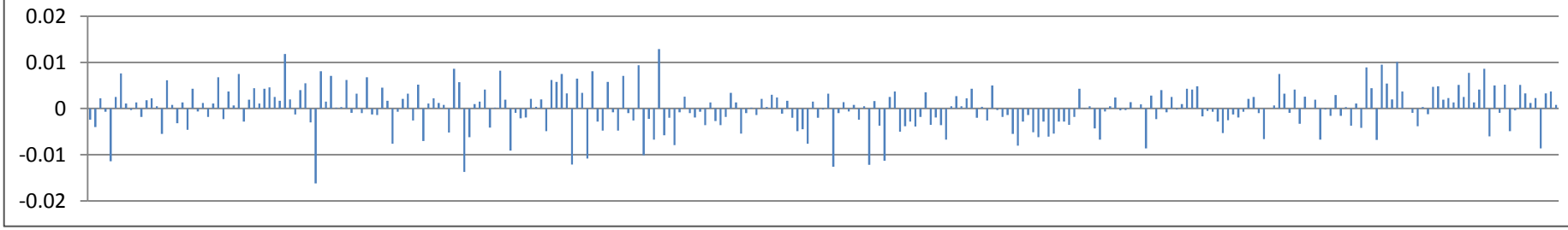
LONGITUDINAL MOVEMENT – Measure of the straightness at 1200 mm scan (- direction)



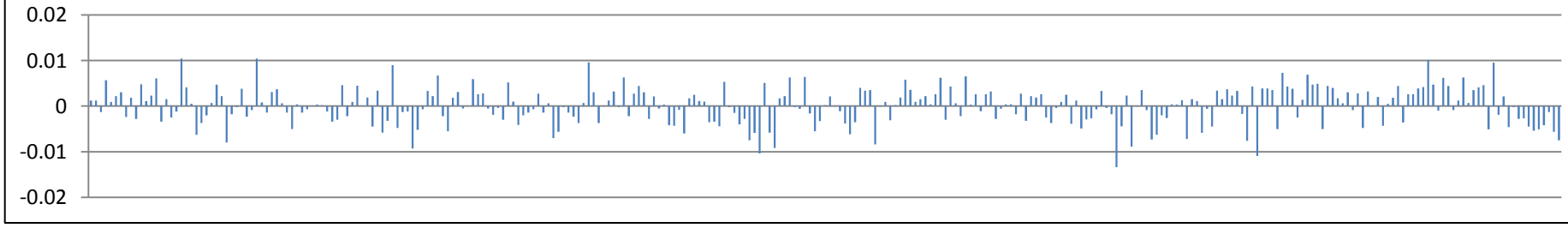
Results: Z Scan



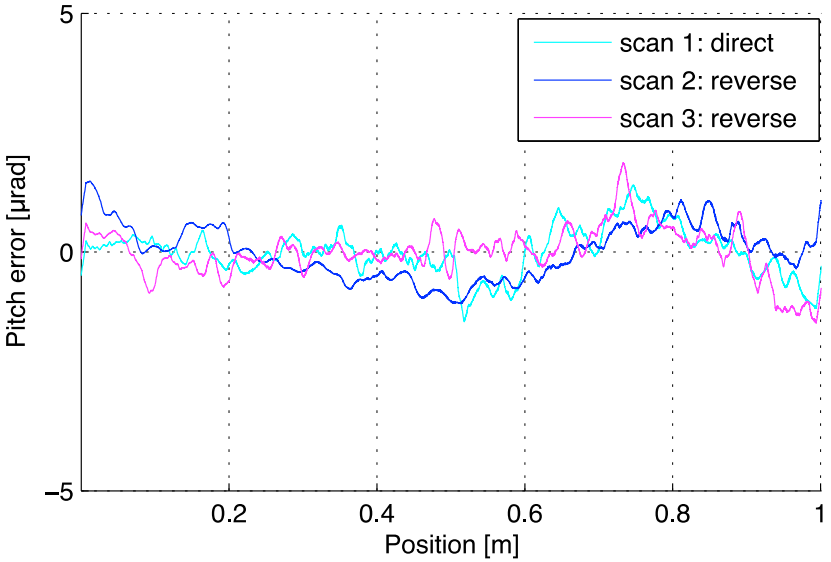
VERTICAL MOVEMENT – Measurement of straightness 100 mm (+ direction)

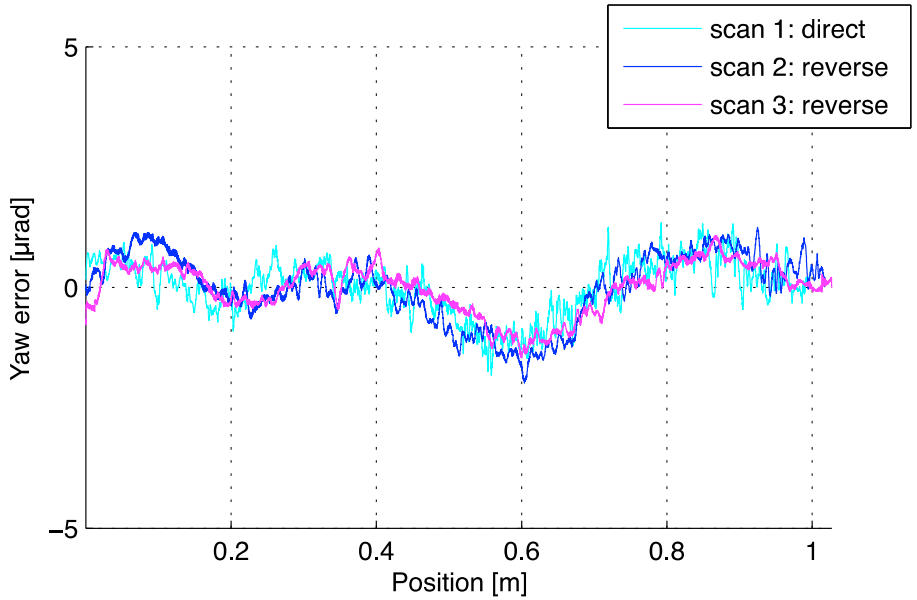


VERTICAL MOVEMENT – Measurement of straigthness 100 mm (- direction)

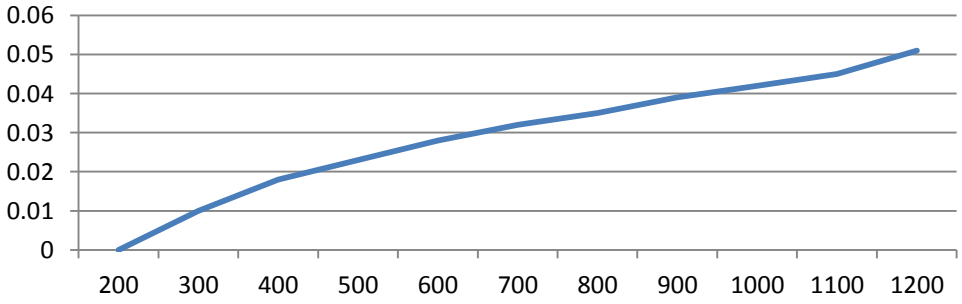


Angle evolution

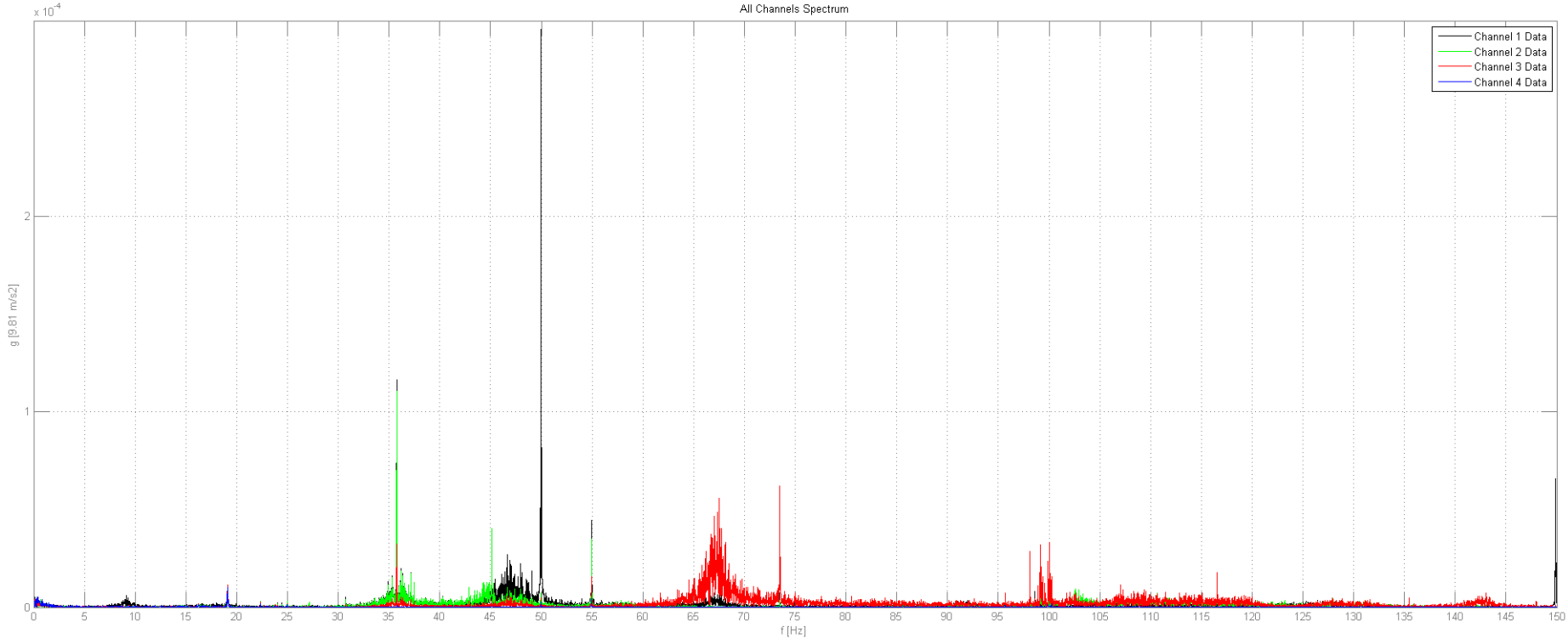


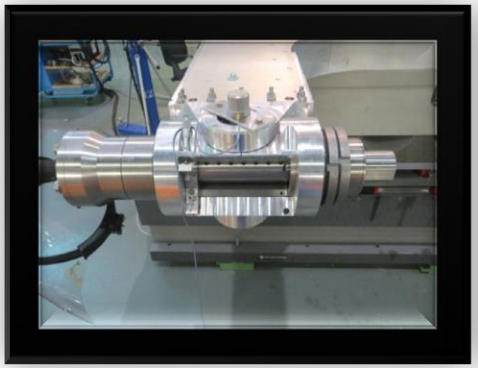


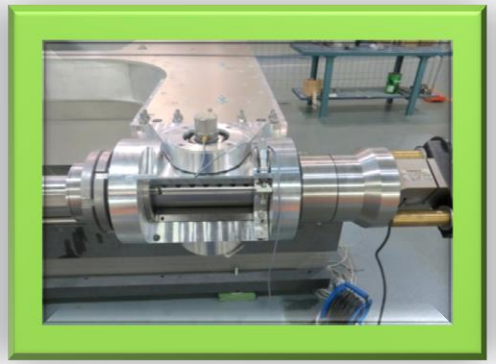
ROLL EVOLUTION MOVING ALONG Y AXIS

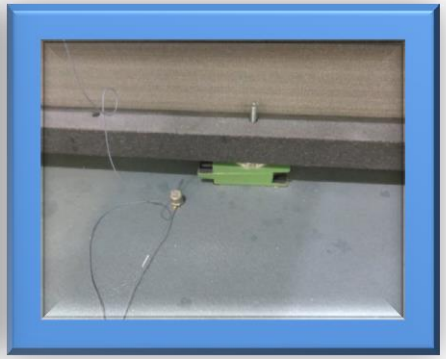


Vibration static

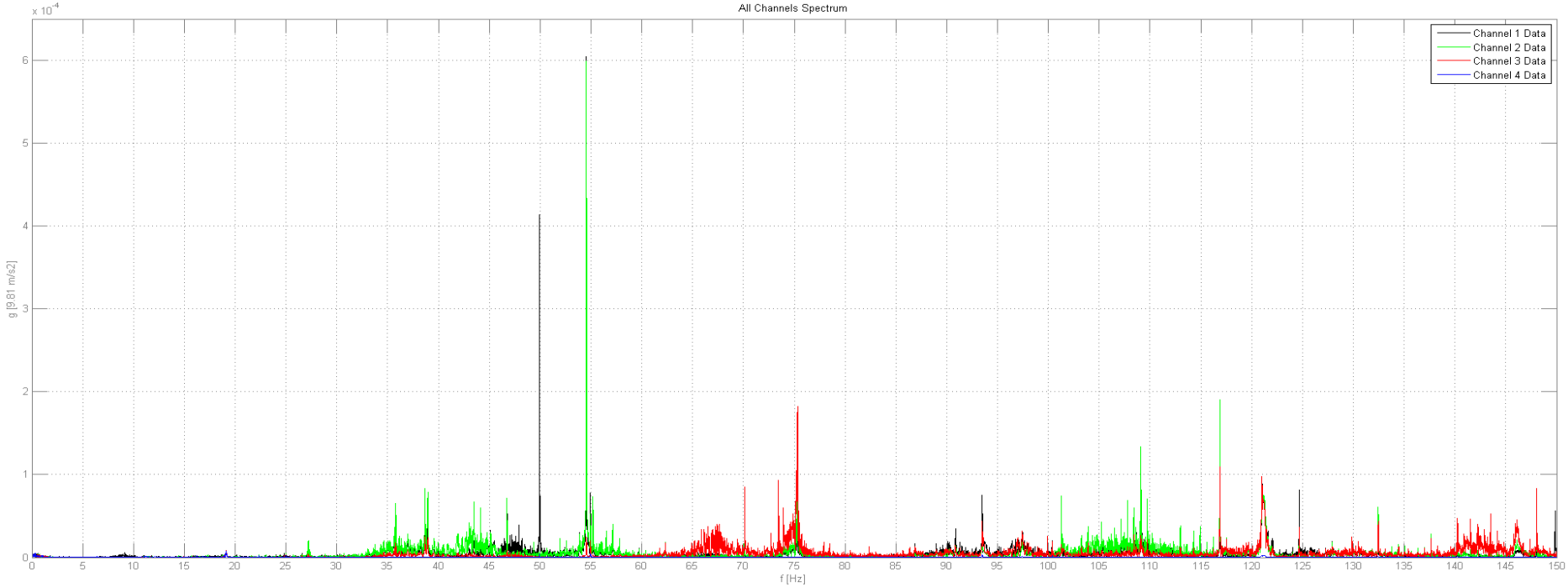


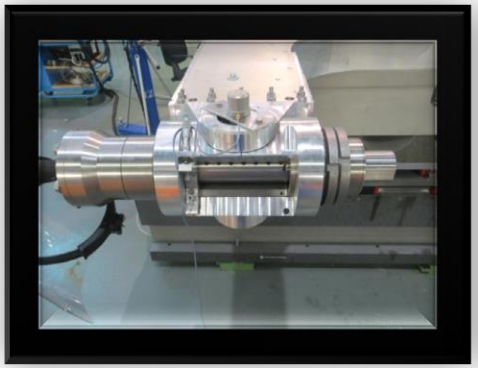


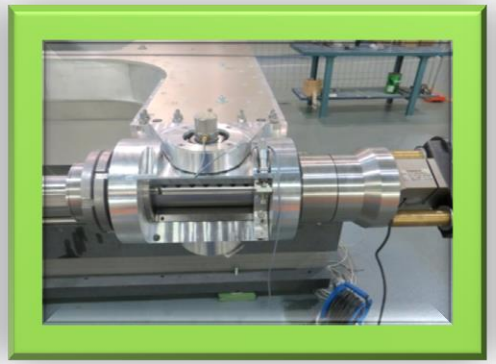


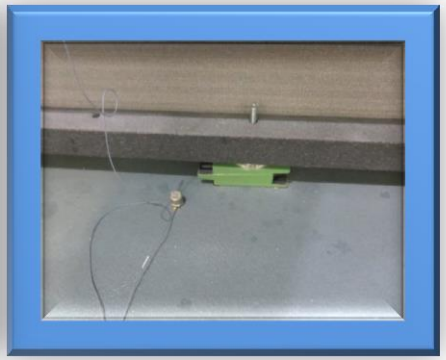


Vibration on movement









Next steps and Conclusions

Next

- Finish the measurements (X scans and repeatability) and prepare a performance report for the ID groupis needed to inform the magnetic measurement group.
- Hall sensor integration and first measurements with a calibration magnet

Conclusions

- Specifications are almost guaranteed
- It can work for very narrow gap closed structures up to open conventional dipoles
- That solution tooks a big space for the operation range
- If this short prototype suceed, a 3 m range bench can be consiereded using this concept

THANKS

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